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Stein et al.

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(54) **WIRELESS CHARGING PLATFORM USING BEAMFORMING FOR WIRELESS SENSOR NETWORK**

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CPC ***H02J 7/025*** (2013.01); ***H02J 50/10*** (2016.02); ***H04B 7/0617*** (2013.01); ***H04W 4/24*** (2013.01);
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(58) **Field of Classification Search**
CPC H05B 33/0845; H02J 9/02; H02J 9/065; H02J 17/00; H02J 5/005; H02J 7/025;
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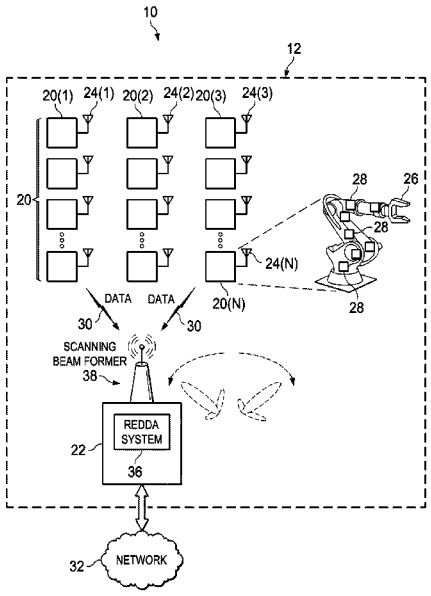
(57) **ABSTRACT**

A wireless charging platform for a wireless sensor network is disclosed, which includes a radio frequency energy distributor and data aggregator (REDDA) system configured to aggregate data from sensor nodes and wirelessly transmit power to the sensor nodes using a beamformed RF signal. The REDDA system can set a radiation pattern for the beamformed RF signal that maximizes RF energy transfer to the sensor nodes based on an environment associated with the sensor nodes. In various embodiments, the REDDA system can include an Internet of Things (IoT) interface connected to an IoT network, and the REDDA system can use information gleaned from the IoT network to set the radiation pattern.

28 Claims, 9 Drawing Sheets



(51) **Int. Cl.**

H04W 72/04	(2009.01)
H04B 7/06	(2006.01)
H02J 50/10	(2016.01)
H04W 4/24	(2018.01)
H04W 4/70	(2018.01)
H04W 88/16	(2009.01)
H04W 4/38	(2018.01)

(52) **U.S. Cl.**

CPC ***H04W 4/70*** (2018.02); ***H04W 72/046*** (2013.01); *H04W 4/38* (2018.02); *H04W 88/16* (2013.01)

(58) **Field of Classification Search**

CPC .. H02J 7/345; H02J 7/0068; H02J 7/34; H02J 9/061; H02J 3/00; H02J 7/32; H02J 50/10; H02J 7/0027; H02J 7/0029; H02J 50/12; H02J 7/35; H02J 50/20; H02J 50/80; H02J 50/40; H02J 50/90; H02J 50/15; H02J 7/00034; H02J 50/30; H02J 50/23; H02J 7/00045; H02J 50/00; H02J 50/27; H02J 50/70; H02J 7/00712; H02J 7/0077; H02J 7/027; H02J 13/00016; H02J 50/50; H02J 7/0042; H02J 7/0047; H02J 7/0048; H02J 7/007; H02J 7/04; H02J 50/402; H02J 50/001; H02J 50/60; H02J 7/0019; H02J 13/00024; H02J 13/00026; H02J 13/0075; H02J 2310/46; H02J 7/00; H02J 7/02; Y02B 20/346; H04B 5/0037; H04B 17/318; H04B 11/00; H04B 1/385; H04B 1/44; H01Q 1/248; H01Q 1/2241; H04L 43/08; H04L 1/1893; H04L 27/3405; H04L 9/0858; H04L 27/366; H04L 27/362; H04L 2025/0335; B60R 2021/23161; B60R 21/20; A61B 5/11; H04W 4/80

USPC 320/106–115

See application file for complete search history.

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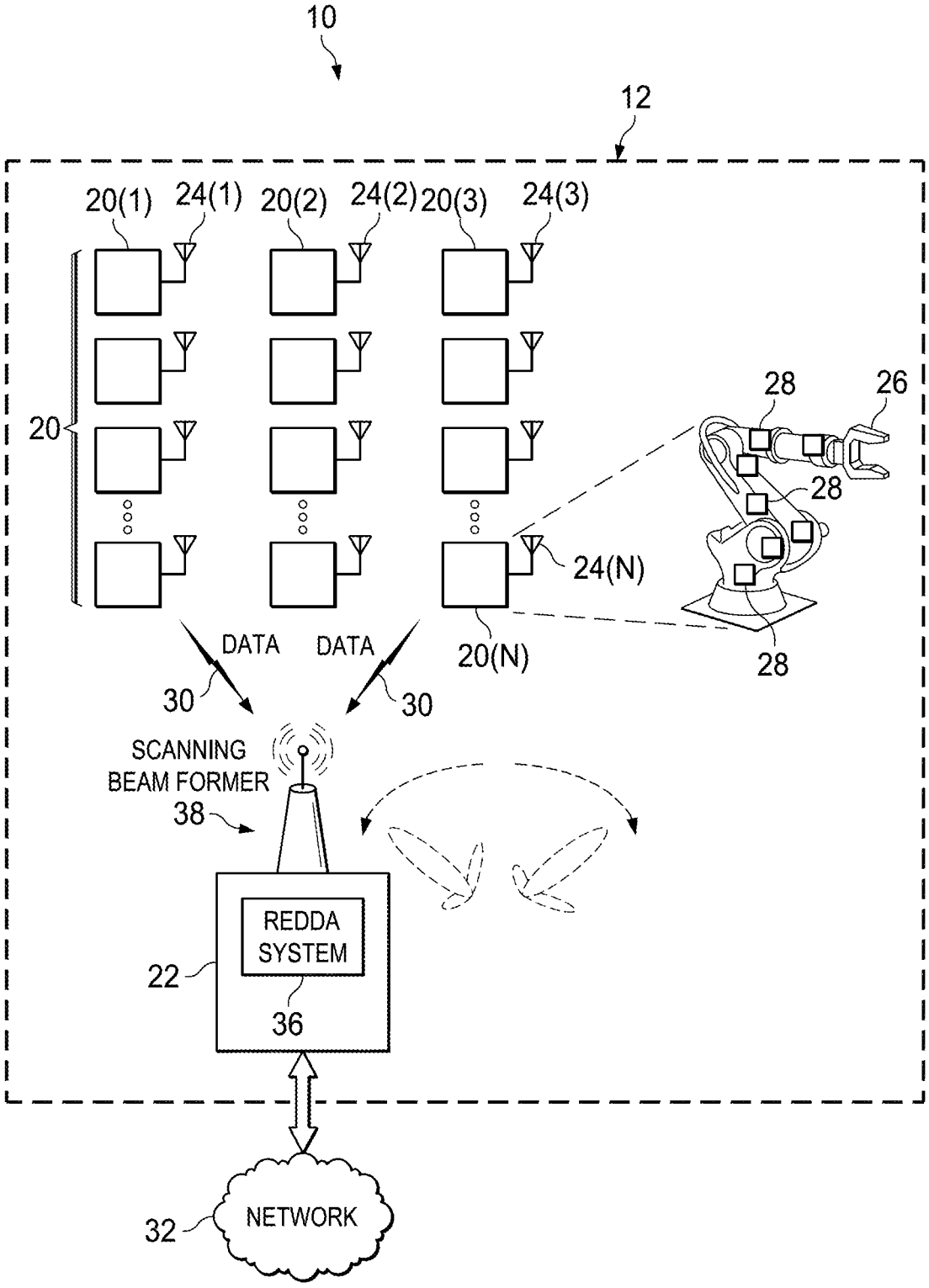
10
12
20(1)
24(1)
20(2)
24(2)
20(3)
24(3)
20
28
26
28
24(N)
20(N)
28
DATA
DATA
30
30
SCANNING
BEAM FORMER
38
REDDA
SYSTEM
22
36
NETWORK
32

FIG. 1

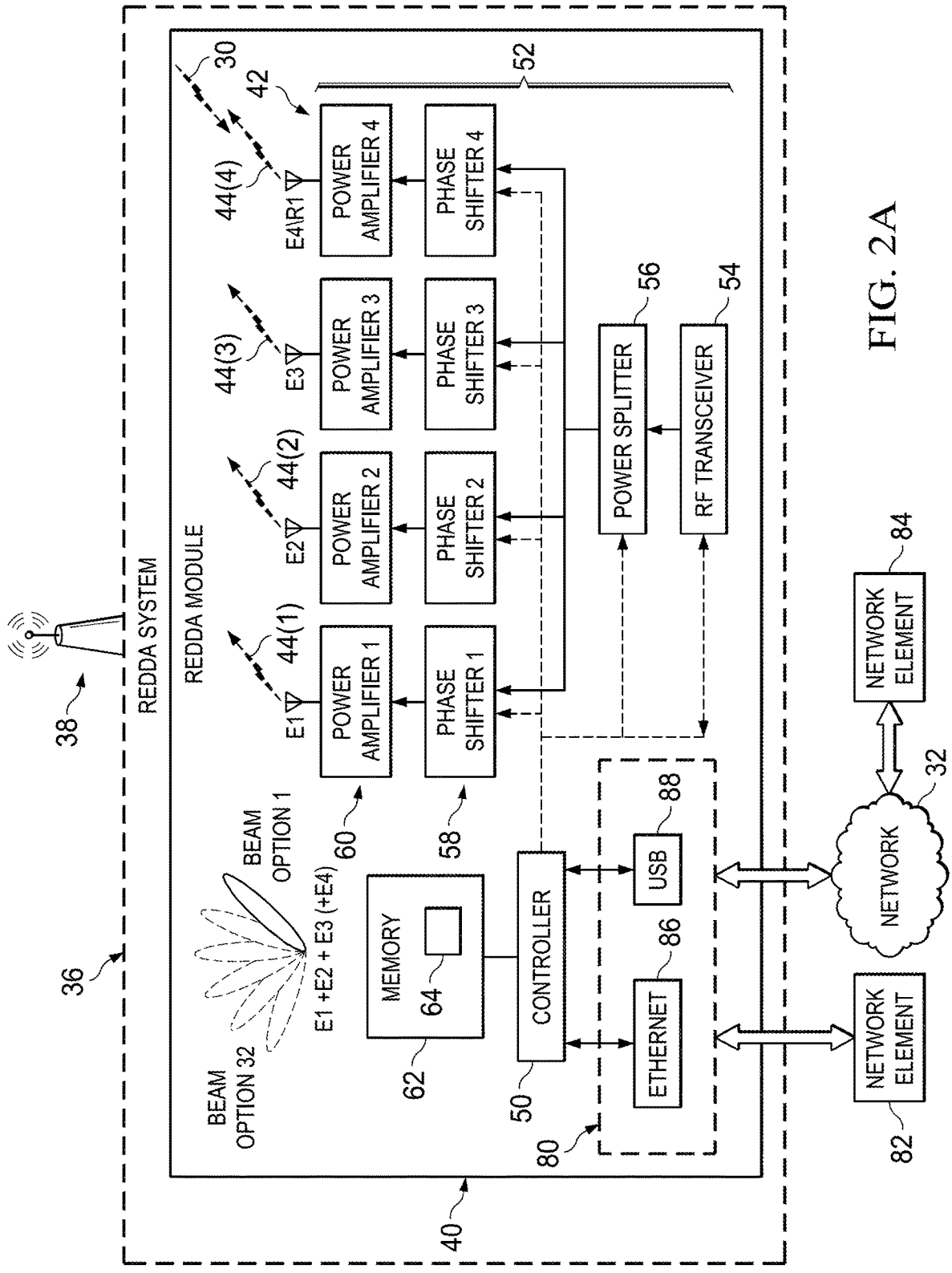
REDDA SYSTEM
REDDA MODULE
38
36
40
30
42
52
44(4)
E4\R1
POWER AMPLIFIER 4
PHASE SHIFTER 4
44(3)
E3
POWER AMPLIFIER 3
PHASE SHIFTER 3
44(2)
E2
POWER AMPLIFIER 2
PHASE SHIFTER 2
44(1)
E1
POWER AMPLIFIER 1
PHASE SHIFTER 1
60
58
POWER SPLITTER
56
RF TRANSCEIVER
54
BEAM OPTION 1
E1 +E2 + E3 (+E4)
BEAM OPTION 32
MEMORY
64
62
CONTROLLER
50
USB
88
ETHERNET
86
80
NETWORK
32
NETWORK ELEMENT
84
NETWORK ELEMENT
82

FIG. 2A

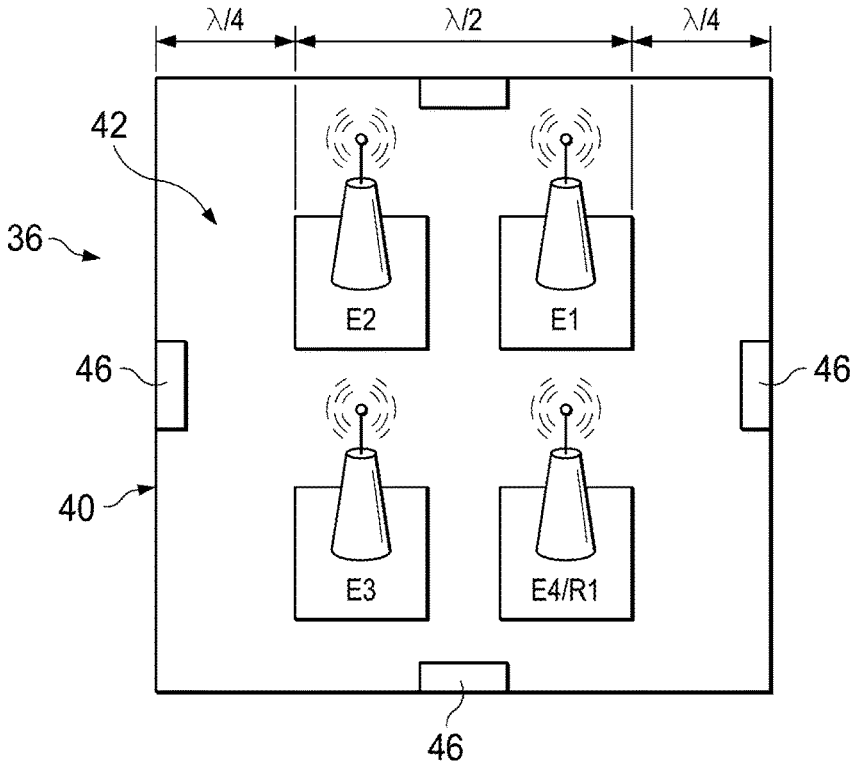

FIG. 2B

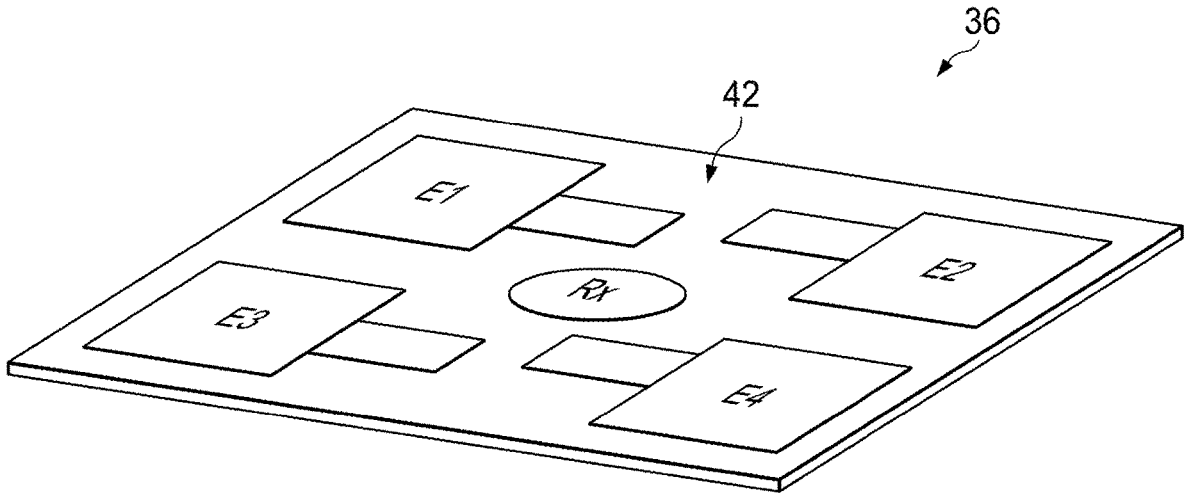

FIG. 2C

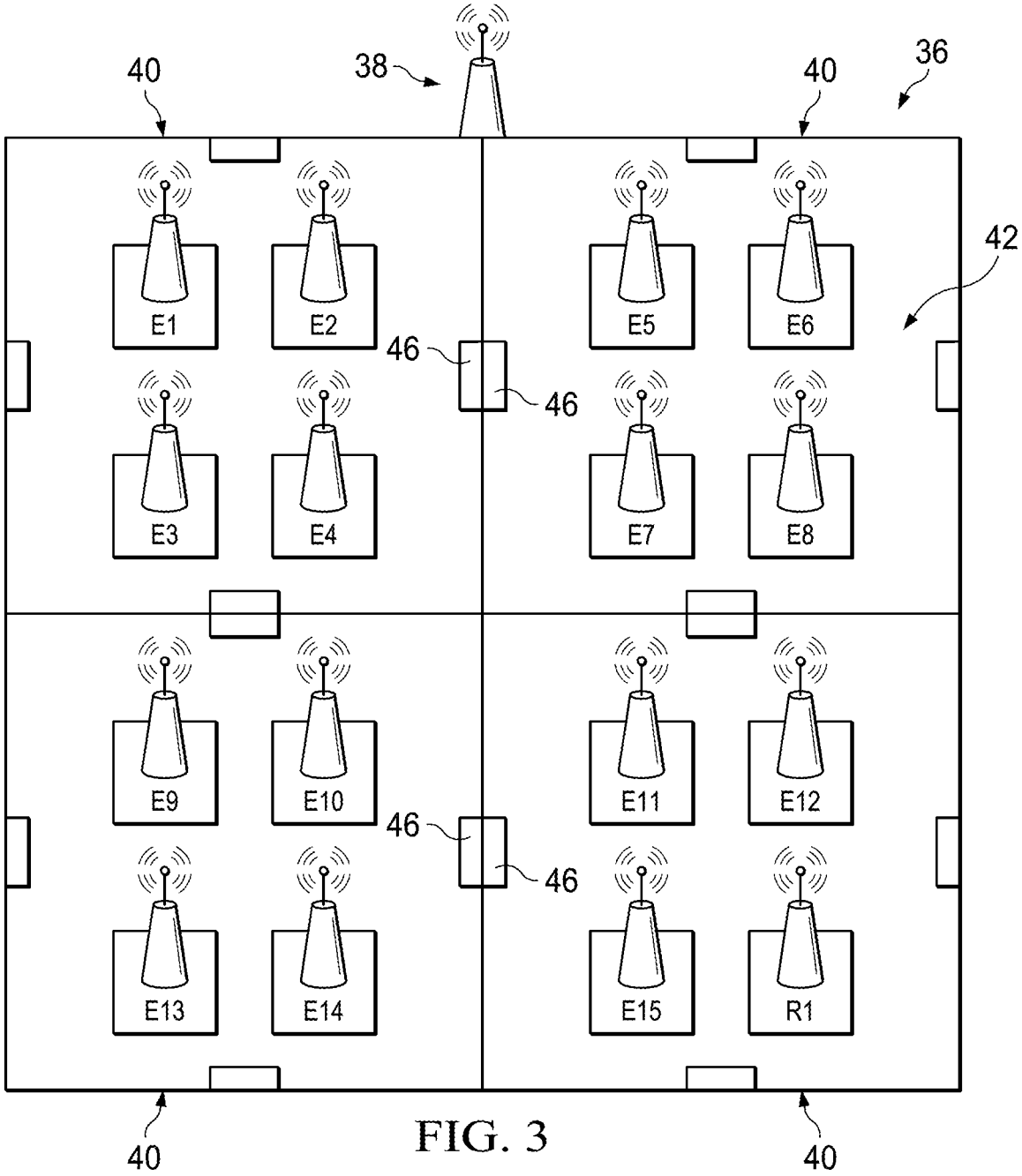
40
38
40
36
42
E1
E2
E5
E6
46
46
E3
E4
E7
E8
E9
E10
E11
E12
46
46
E13
E14
E15
R1
40
40

FIG. 3

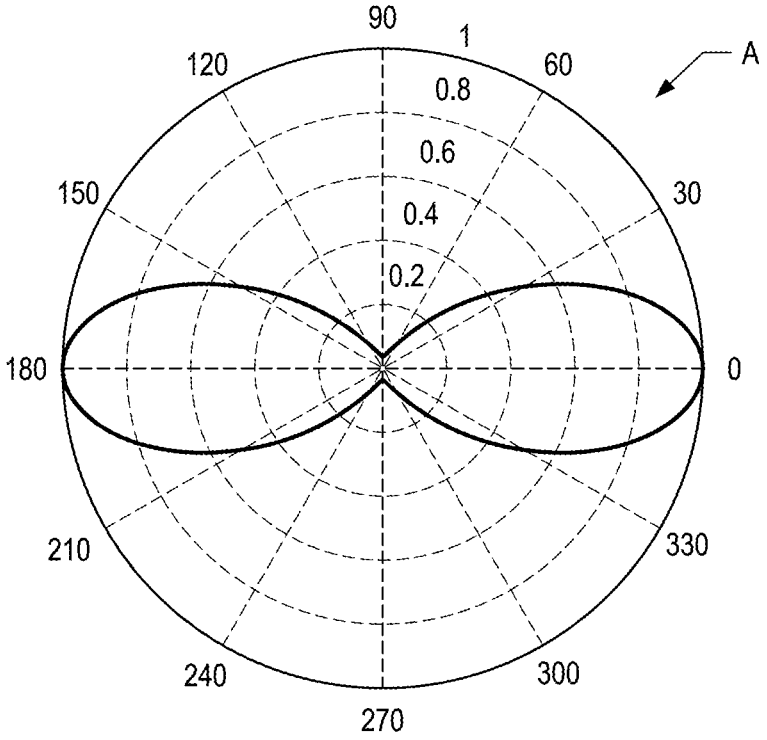
90
1
120
60
A
0.8
0.6
150
30
0.4
0.2
180
0
210
330
240
300
270

FIG. 4A

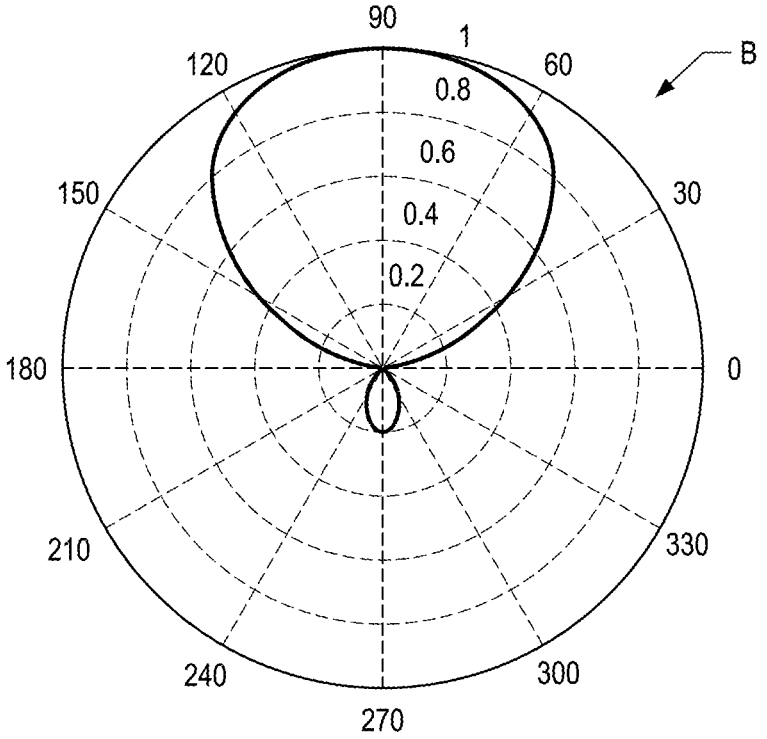
90
1
120
60
B
0.8
0.6
150
30
0.4
0.2
180
0
210
330
240
300
270

FIG. 4B

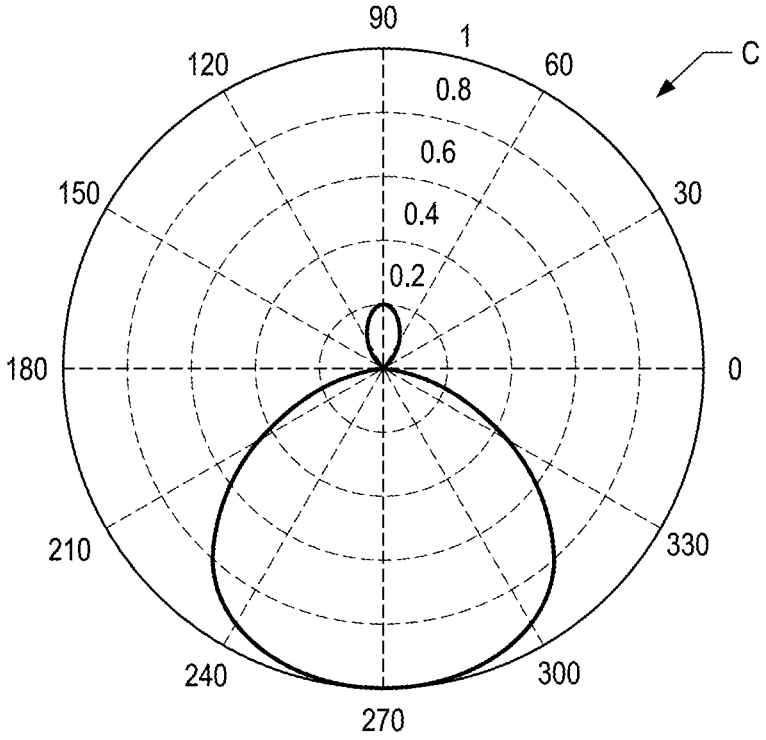
90
1
120
60
C
0.8
0.6
150
30
0.4
0.2
180
0
210
330
240
300
270

FIG. 4C

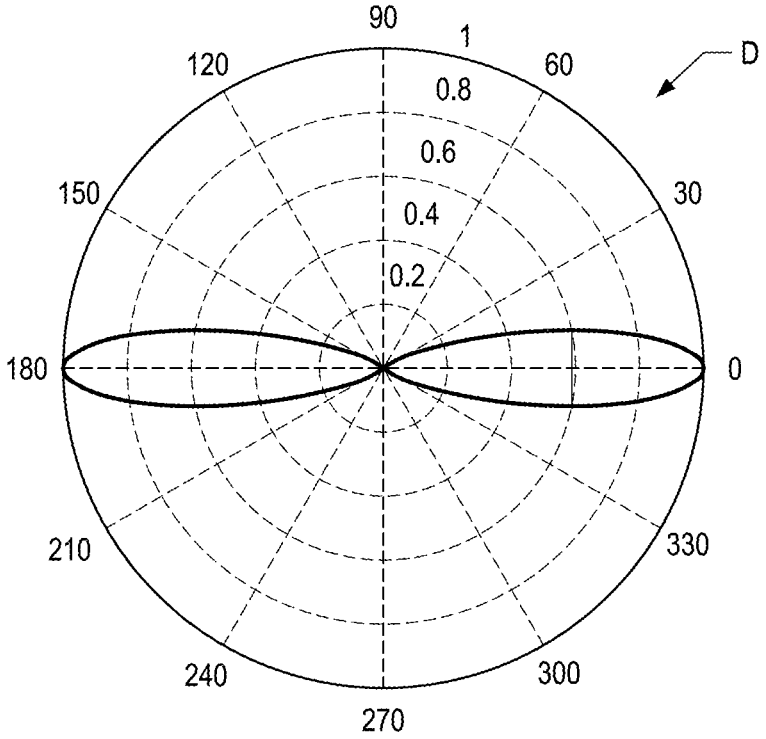
90
1
120
60
D
0.8
0.6
150
30
0.4
0.2
180
0
210
330
240
300
270

FIG. 4D

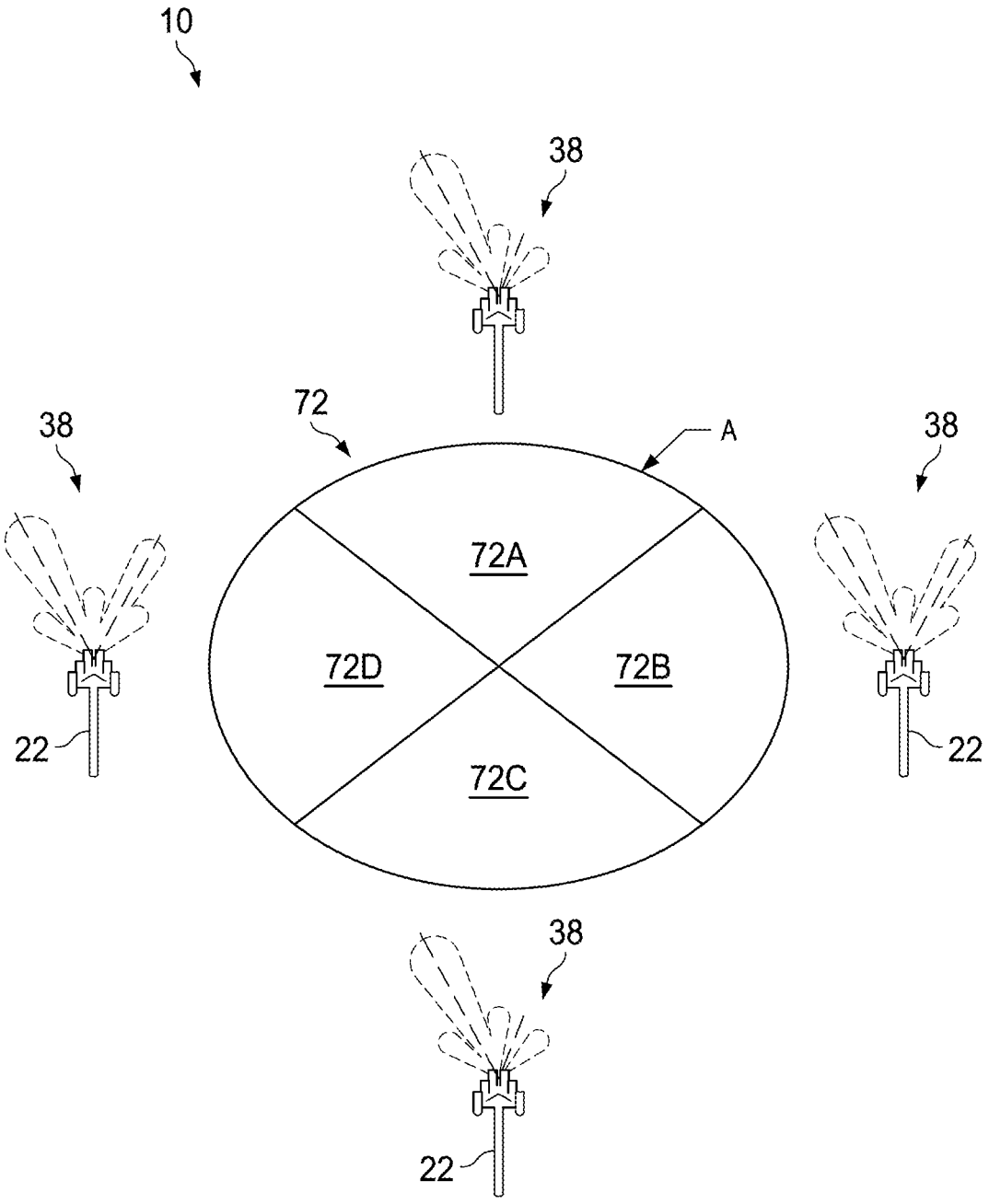

FIG. 5

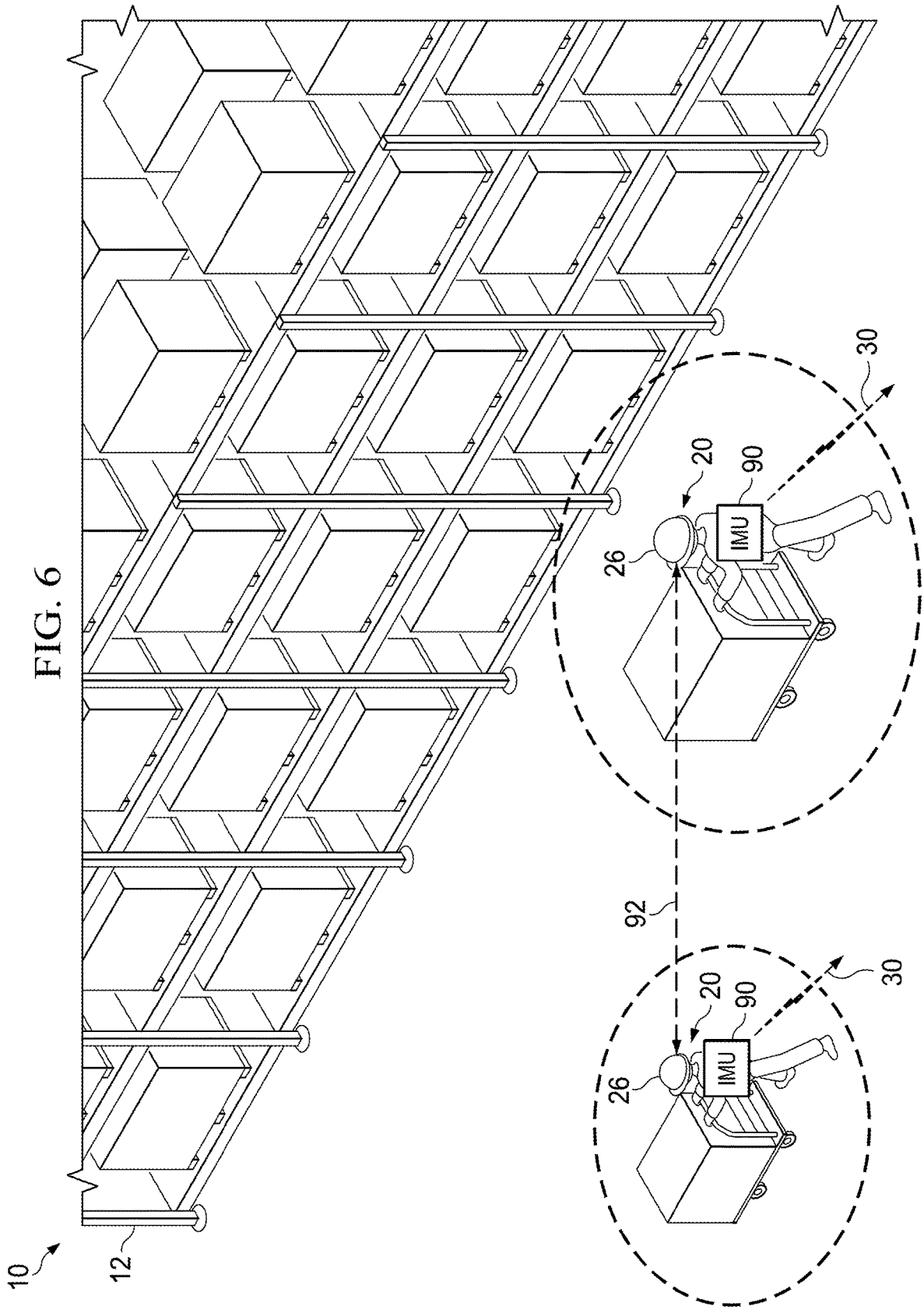

FIG. 6

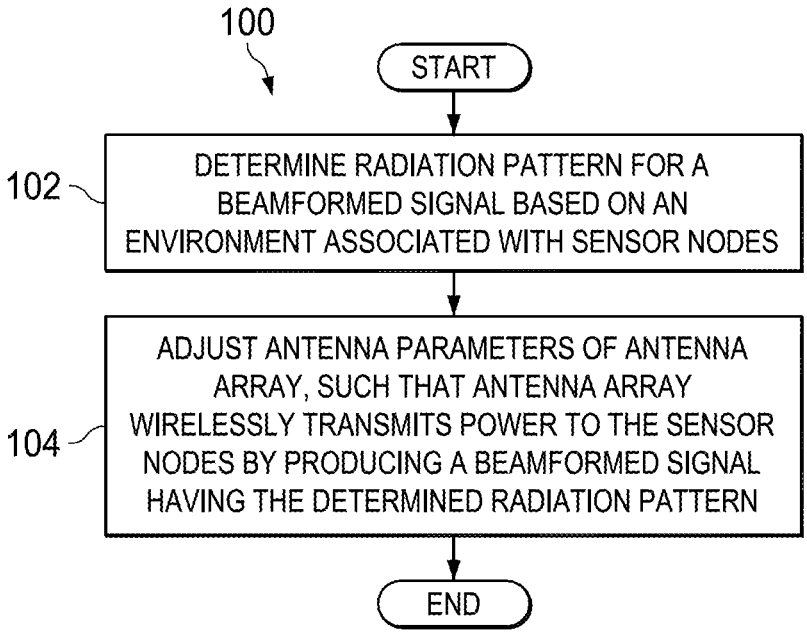
100
START
102
DETERMINE RADIATION PATTERN FOR A BEAMFORMED SIGNAL BASED ON AN ENVIRONMENT ASSOCIATED WITH SENSOR NODES
104
ADJUST ANTENNA PARAMETERS OF ANTENNA ARRAY, SUCH THAT ANTENNA ARRAY WIRELESSLY TRANSMITS POWER TO THE SENSOR NODES BY PRODUCING A BEAMFORMED SIGNAL HAVING THE DETERMINED RADIATION PATTERN
END

FIG. 7A

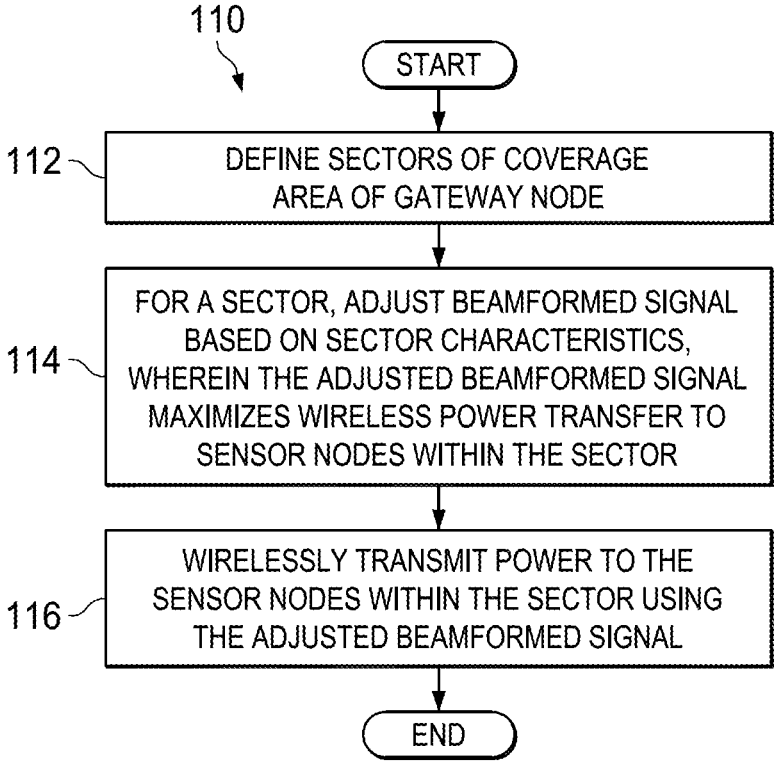
110
START
112
DEFINE SECTORS OF COVERAGE AREA OF GATEWAY NODE
114
FOR A SECTOR, ADJUST BEAMFORMED SIGNAL BASED ON SECTOR CHARACTERISTICS, WHEREIN THE ADJUSTED BEAMFORMED SIGNAL MAXIMIZES WIRELESS POWER TRANSFER TO SENSOR NODES WITHIN THE SECTOR
116
WIRELESSLY TRANSMIT POWER TO THE SENSOR NODES WITHIN THE SECTOR USING THE ADJUSTED BEAMFORMED SIGNAL
END

FIG. 7B

WIRELESS CHARGING PLATFORM USING BEAMFORMING FOR WIRELESS SENSOR NETWORK

TECHNICAL FIELD

The present disclosure relates generally to wireless network environments, and more particularly, to wireless charging in wireless network environments.

BACKGROUND

Radio frequency (RF) system and wireless sensor network (WSN) are two technologies integrated to provide a wide variety of applications, particularly where merging the physical world with the digital world (also referred to as the virtual world). For example, where energy-constraints confine network performance of a wireless sensor network, RF energy harvesting schemes can be implemented to provide power (energy) to various nodes of the wireless sensor network, while further extending sensing capabilities of the wireless sensor network. In such scenarios, wireless power is efficiently and optimally transmitted to the various nodes. Although existing wireless power transmission systems and methods in wireless network environments have been generally adequate for their intended purposes, they have not been entirely satisfactory in all respects.

BRIEF DESCRIPTION OF DRAWINGS

The present disclosure is best understood from the following detailed description when read with the accompanying figures. It is emphasized that, in accordance with the standard practice in the industry, various features are not drawn to scale and are used for illustration purposes only. In fact, the dimension of the various features may be arbitrarily increased or reduced for clarity of discussion.

FIG. **1** is a schematic block diagram of an exemplary communications system for optimizing wireless power transmission in a network environment according to various aspects of the present disclosure.

FIG. **2**A, FIG. **2**B, and FIG. **2**C are schematic block diagrams of an exemplary gateway node that uses beamforming mechanisms for transmitting wireless power in a network environment according to various aspects of the present disclosure.

FIG. **3** is a schematic block diagram of an exemplary antenna array for wirelessly transmitting power that can be implemented in a gateway node, such as the gateway node illustrated in FIGS. **2**A-**2**C, according to various aspects of the present disclosure.

FIG. **4**A, FIG. **4**B, FIG. **4**C, and FIG. **4**D illustrate array factors that can be achieved by a gateway node, such as the gateway node illustrated in FIGS. **2**A-**2**C, to vary a radiation pattern of a beamformed signal for transmitting wireless power according to various aspects of the present disclosure.

FIG. **5** is a schematic diagram of an exemplary beamformer sector profile table that can be implemented by a gateway node for transmitting wireless power, such as the gateway node illustrated in FIGS. **2**A-**2**C, to maximize wireless power transmission according to various aspects of the present disclosure.

FIG. **6** is a schematic diagram of an exemplary communication system that provides location awareness to a gateway node for transmitting wireless power, such as the gateway node illustrated in FIGS. **2**A-**2**C, according to various aspects of the present disclosure.

FIG. **7**A and FIG. **7**B are simplified flowcharts of exemplary wireless power transmission methods that can be implemented by a gateway node to wirelessly charge sensor nodes, such as the gateway node illustrated in FIGS. **2**A-**2**C, according to various aspects of the present disclosure.

OVERVIEW OF EXAMPLE EMBODIMENTS

A wireless charging platform for a wireless sensor network and associated wireless charging method are disclosed herein. In various embodiments, the wireless charging platform includes a radio frequency energy distributor and data aggregator (REDDA) system that aggregates data from sensor nodes and wirelessly transmits power to the sensor nodes using a beamformed RF signal. In various embodiments, the wireless charging platform can include a radio frequency identification (RFID) reader that includes the REDDA system. In various embodiments, the wireless charging platform can include a gateway node that includes the REDDA system. In some embodiments, the RFID reader acts as a gateway node.

The REDDA system can set a radiation pattern for the beamformed RF signal that maximizes RF energy transfer to the sensor nodes based on an environment associated with the sensor nodes. The radiation pattern for the beamformed RF signal can be set to achieve a defined quality of service for RF energy transfer. By setting the radiation pattern of the beamformed signal, the REDDA system can selectively power on/off at least one sensor node having no battery, and/or selectively charge a battery of at least one sensor node. In various embodiments, the REDDA system aggregates data from the sensor node and wirelessly transmits power to the sensor nodes on different radio bands.

The REDDA system can include an Internet of Things (IoT) interface connected to an IoT network, and the REDDA system can use information gleaned from the IoT network to set the radiation pattern. For example, the REDDA system can glean information about the environment associated with the sensor nodes from the IoT network.

In various embodiments, the REDDA system includes an electronically steered antenna array for transmitting the beamformed RF signal. Each antenna of the antenna array has an associated extinction coefficient and an associated progressive phase shift, and the REDDA system is configured to set the associated extinction coefficients and progressive phase shifts to achieve the defined qualify of service. The antenna array can be formed by one or more REDDA modules to provide various antenna array configurations. Each REDDA module includes at least one communication port for connecting to another REDDA module.

A method for wirelessly charging sensor nodes using a beamformed signal produced by an antenna array can include determining a radiation pattern for the beamformed signal based on an environment associated with the sensor nodes, and adjusting antenna parameters of the antenna array, such that the antenna array wirelessly transmits power to the sensor nodes by producing a beamformed signal having the determined radiation pattern.

DETAILED DESCRIPTION OF EXAMPLE EMBODIMENTS

Radio frequency (RF) system and wireless sensor network (WSN) are two technologies integrated to provide a wide variety of applications, particularly where merging the physical world with the digital world (also referred to as the virtual world). FIG. **1** is a schematic block diagram of an

exemplary communications system **10** for optimizing wireless charging (also referred to as wireless power transmission) in a network environment according to various aspects of the present disclosure. FIG. **1** has been simplified for the sake of clarity to better understand the inventive concepts of the present disclosure. Additional features can be added in communications system **10**, and some of the features described can be replaced or eliminated in other embodiments of communications system **10**.

In FIG. **1**, communications system **10** includes a wireless network system **12**, such as a wireless sensor network. Wireless network system **12** includes sensor nodes **20** that communicate wirelessly with a gateway node **22**. Each sensor node **20** can collect data from its surrounding environment (e.g., wireless network system **12**) and communicate the collected data via data signals to gateway node **22** for further processing. Any number of sensor nodes **20**, and in some embodiments any number of gateway nodes **22**, can be provided within wireless network system **12**. In various embodiments, wireless network system **12** can include hundreds or even thousands of sensor nodes **20**, where at least one gateway node **22** is used to communicate with the sensor nodes **20**. For purposes of the following discussion, and in various embodiments, wireless network system **12** represents a radio frequency identification (RFID) system, where sensor nodes **20** include RFID tags that store data, and gateway node **22** includes an RFID reader that communicates wirelessly with the RFID tags to collect data from and charge (power) the RFID tags. In various embodiments, sensor nodes **20** can be distributed throughout a location, for example, within and/or around a building, such as a warehouse, where gateway node **22** can track information associated with the building or objects, people, animals, and/or entities (collectively referred to as things) associated with the building. In various embodiments, sensor nodes **20** and gateway node **22** wirelessly communicate using any appropriate communication standard, including Wi-Fi (for example, IEEE 802.11), Bluetooth, an IEEE 802.15.x communication standard (such as SmartGrid IEEE 802.15.4g and/or WBAN IEEE 802.15.6g), other appropriate communication standard, and/or variations thereof.

Sensor nodes **20** can include sensor nodes **20**(**1**), **20**(**2**), **20**(**3**), . . . , **20**(N) having associated antennas **24**(**1**), **24**(**2**), **24**(**3**), . . . , **24**(N), where N is a total number of sensor nodes **20** in wireless network system **12**. Each sensor node **20** can include a sensing unit, a processor, an RF transceiver, and an energy source (also referred to as a power source). Depending on applications of wireless network system **12**, sensor nodes **20** may have identical or varying sensing, processing, transmitting, receiving, and/or powering capabilities. The sensing unit includes one or more sensors, such as optical, magnetic, mechanical, thermal, biological, chemical, visual, infrared, and/or other type of sensors for monitoring various parameters within or around wireless network system **12**. In various embodiments, each sensor node **20** can represent a robot. For example, sensor node **20**(N) includes a robot **26** having various sensors **28** (seven sensors in the depicted embodiment), where gateway node **22** can wirelessly collect data from each sensor **28**. The power source of sensor nodes **20** can be an internal power source, such as a battery internal to sensor nodes **20** (for example, where sensor nodes **20** include an active RFID tag), an external power source, such as RF energy received from gateway node **22** (for example, where sensor nodes **20** include a passive RFID tag), or a combination thereof (for example, where sensor nodes **20** include a semi-passive RFID tag). In various embodiments, as described further below, sensor nodes **20** wirelessly derive at least a portion of power from gateway node **22**, particularly from energy, such as RF energy, from gateway node **22**. In various embodiments, each sensor node **20** includes an energy harvesting mechanism for deriving, capturing, and storing energy from external sources (for example, RF energy from gateway node **22**). In some embodiments, sensor nodes **20** operate solely off RF energy harvested from gateway node **22**.

As noted, gateway node **22** can aggregate data collected by sensor nodes **20**. In various embodiments, gateway node **22** receives data signals **30** from sensor nodes **20** (including from each sensor **28** of sensor nodes **20**), which include information about the surrounding environment of each sensor node **20**. Gateway node **22** can communicate the collected data to network elements of wireless network system **12** or to network elements over a network **32**. In various embodiments, gateway node **22** communicates with a host computer system and/or host database within wireless network system **12** or with host computer system and/or host database over network **32**, which can communicate with an application for processing information collected from sensor nodes **20**. Alternatively, in various embodiments, gateway node **22** can communicate directly with an application over network **32**. As used herein, the term "network element" can encompass computers, network appliances, servers, routers, switches, gateways, bridges, load balancers, firewalls, processors, modules, or any other suitable device, component, element, or object operable to exchange information in a network environment, such as communication system **10**. Moreover, the network elements may include any suitable hardware, software, components, modules, interfaces, or objects that facilitate the operations thereof. This may be inclusive of appropriate algorithms and communication protocols that allow for the effective exchange of data or information.

In various embodiments, communication system **10** represents an Internet of Things (IoT) system, where things (for example, objects, people, animals, and/or entities) and sensors within or attached to these things are connected to the Internet. The things can be connected to the Internet via wireless and/or wired connections. For example, in various embodiments, network **32** is the Internet, and gateway node **22** includes an IoT interface that connects gateway node **22** to network **32**, such that information collected by sensor nodes **20** can be communicated to network elements and/or applications over the Internet. In various embodiments, gateway node **22** wirelessly communicates with network elements and/or applications over the Internet. In such embodiments, wireless network system **12** can serve as a backhaul network, and in some embodiments, where wireless network system **12** includes a host computer system connected to gateway node **22**, the host computer system can serve as a backhaul computer. Furthermore, communication system **10** may be configured over a physical infrastructure that includes one or more networks and, further, can be configured in any form including, but not limited to, local area networks (LANs), wireless local area networks (WLANs), virtual local area networks (VLANs), metropolitan area networks (MANs), wide area networks (WANs), virtual private networks (VPNs), Internet, Intranet, Extranet, any other appropriate architecture or system, or any combination thereof that facilitates communications as described herein. In some embodiments, communication links may represent any electronic link supporting a LAN environment such as, for example, cable, Ethernet, wireless technologies (for example, IEEE 802.11x), ATM, fiber optics, or any suitable combination thereof. In other embodiments, com-

munication links may represent a remote connection through any appropriate medium (such as digital subscriber lines, telephone lines, T1 lines, T3 lines, wireless, satellite, fiber optics, cable, Ethernet, etc. or any combination thereof) and/or through any additional networks.

As further noted, gateway node **22** can wirelessly charge sensor nodes **20**, for example, by wirelessly transmitting power to sensor nodes **20**. In the depicted embodiment, gateway node **22** includes a radio frequency energy distributor and data aggregator (REDDA) system **36** that aggregates data from sensor nodes **20** and wirelessly transmits power to sensor nodes **20** using a beamformed signal **38**, such that sensor nodes **20** can operate using energy harvested from beamformed signal **38**. In various embodiments, REDDA system **36** aggregates data from sensor nodes **20** and wirelessly transmits power to sensor nodes **20** on different radio bands, such as different ISM radio bands. For example, REDDA system **36** receives data signals **30** from sensor nodes **20** on a narrowband radio, and wirelessly transmits power via beamformed signal **38** to sensor nodes **20** on a wideband radio. Using different radio bands for aggregating and transmitting can prevent (or minimize) collision of data signals **30** and/or beamformed signal **38** and/or minimize data retransmission. In various embodiments, REDDA system **36** can include a wideband aggregator receiver, and sensor node **20** can include a sensor narrowband radio, where REDDA system **36** can aggregate data from the sensor narrowband radio using the wideband aggregator receiver in a manner that avoids data collision and minimizes data retransmission. In various embodiments, REDDA system **36** can scan in a frequency ISM band ranging from about 902 MHz to about 928 MHz (an unlicensed frequency ISM band for North America). Within this frequency band, REDDA system **36** can allocate about 10 MHz for wirelessly transmitting power, and about 16 MHz for aggregating data. In various embodiments, sensor nodes **20** can be configured with narrowband modulators (for example, IEEE 802.15.4g narrowband modulators) using a frequency band having a bandwidth that ranges from about 50 KHz to about 200 KHz for transmitting data.

FIG. **2**A, FIG. **2**B, and FIG. **2**C are schematic block diagrams of an exemplary REDDA system **36**, which can be implemented in gateway node **22**, according to various aspects of the present disclosure. REDDA system **36** can be implemented using distributed various integrated circuits and/or devices interconnected with each other, such that components of REDDA system **36** are integrated to provide the functions described herein. FIG. **2**A, FIG. **2**B, and FIG. **2**C have been simplified for the sake of clarity to better understand the inventive concepts of the present disclosure. Additional features can be added in REDDA system **36**, and some of the features described can be replaced or eliminated in other embodiments of REDDA system **36**.

REDDA system **36** includes a REDDA module **40** that aggregates data signals **30** from sensor nodes **20** and produces beamformed signal **38** for wirelessly charging sensor nodes **20**. For example, REDDA module **40** includes an antenna array **42** having multiple antennas (elements) E**1**, E**2**, E**3**, and E**4** that transmit associated RF signals **44**(**1**), **44**(**2**), **44**(**3**), and **44**(**4**) (collectively referred to as RF signals **44**) to achieve various radiation patterns for beamformed signal **38**. As described in detail below, REDDA module **40** uses different radiation patterns for beamformed signal **38** to optimize wireless power transmission. In FIG. **2**A and FIG. **2**B, REDDA module **40** includes an antenna that both receives and transmits RF signals, such as antenna E**4**/R**1** that both receives data signals **30** and transmits associated RF signal **44**(**4**). Alternatively, as depicted in FIG. **2**C, in some embodiments, REDDA module **40** can include a separate antenna, such as antenna RX, for receiving data signals **30**. In various implementations, REDDA module **40** includes a single antenna for receiving data signals **30** to collect information from sensor nodes **20**. Alternatively, REDDA module **40** can include more than one antenna for receiving data signals **30**.

In various embodiments, antenna array **42** can include a linear array, a circular array, a planar array, a conformal array, or other type of array. In FIGS. **2**A-**2**C, antenna array **42** includes a two-dimensional antenna array, such as a 2×2 planar antenna array, for transmitting beamformed signal **38**. Alternatively, antenna array **42** can have other dimensions, for example, a 2×4 planar antenna array, a 4×4 planar antenna array, or other dimension depending on design considerations of REDDA system **36** and/or REDDA module **40**. REDDA module **40** includes at least one communication port **46** for connecting to other REDDA modules, such that REDDA system **36** has a fully configurable antenna array. Such configurability facilitates various antenna array configurations, providing great flexibility in achieving various radiation patterns depending on design considerations of wireless network system **12**, sensor nodes **20**, and/or REDDA system **36**. FIG. **3** is a schematic block diagram of an exemplary REDDA system **36** that includes multiple REDDA modules **40**, which can be implemented in gateway node **22**, according to various aspects of the present disclosure. For example, REDDA system **36** includes four REDDA modules **40** interconnected via communication ports **46**, providing a 4×4 planar antenna array **42** that includes antennas (elements) E**1**, E**2**, E**3**, E**4**, E**5**, E**6**, E**7**, E**8**, E**9**, E**10**, E**11**, E**12**, E**13**, E**14**, and E**15** for transmitting associated RF signals to provide beamformed signal **38**. A receiving antenna R**1** is also provided for receiving data signals **30** from sensor nodes **20**. In various embodiments, receiving antenna R**1** can also transmit an associated RF signal to provide beamformed signal **38**. FIG. **3** has been simplified for the sake of clarity to better understand the inventive concepts of the present disclosure. Additional features can be added in REDDA system **36**, and some of the features described can be replaced or eliminated in other embodiments of REDDA system **36**.

Returning to FIGS. **2**A-**2**C, REDDA module **40** is configured such that antenna array **42** is an electronically steered antenna array (for example, by varying signal phases of each antenna within antenna array **42**), which can achieve various radiation patterns for beamformed signal **38**. REDDA module **40** includes a controller **50** that controls data signal processing and wireless power transmitting of antenna array **42**. In various embodiments, controller **50** is programmable digital logic, such as a field programmable gate array (FPGA). Alternatively, controller **50** can be implemented as another programmable logic device, a processor, an application specific integrated circuit (ASIC), a digital signal processor (DSP), a microcontroller, a microprocessor, a processing module, other suitable controller, or a combination thereof. Controller **50** implements beamforming to achieve various radiation patterns for beamformed signal **38**. Generally, beamforming involves combining RF signals **44** associated with antennas of the antenna array **42** in a way that some RF signals experience constructive interference, while other RF signals experience destructive interference. In various embodiments, controller **50** adjusts various antenna array parameters of antenna array **42** to achieve various radiation patterns for beamformed signal **38**, including generally array shape (linear, circular, planar, or

other array shape depending on a desired radiation pattern), antenna spacing, antenna excitation coefficients (for example, excitation amplitude and/or excitation phase), pattern of antennas in the antenna array, and/or other antenna array parameters.

For example, an array factor (AF) associated with antenna array **42** can be varied to achieve different radiation patterns. The array factor depends on geometry of antenna array **42** and excitation coefficients (e.g., amplitude and/or phase) associated with antennas of antenna array **42**. In various embodiments, an array factor ($AF_{x1}=S_{XM}$) for a linear array of M antennas along an x-axis of antenna array **42** can be represented by the following equation:

$$S_{X_M} = AF_{x1} = \sum_{m=1}^{M} I_{m1} e^{j(m-1)(kd_x \sin\theta\cos\Phi+\beta_x)}$$

where I_{m1} (m=1, . . . , M) is an excitation amplitude of an antenna of antenna array **42** at a point represented by $x=(m-1)d_x$; d_x is a distance between antennas of antenna array **42** in an x-direction (for simplicity, assume antennas of antenna array **42** are equispaced); β_x represents a progressive phase shift (a phase shift between adjacent antennas of antenna array **42** in the x-direction); and sin θ cos Φ is a directional cosine with respect to the x-axis. Similarly, if N such linear arrays are situated along a y-axis of antenna array **42** (thereby forming a rectangular array), an array factor ($AF_{y1}=S_{YN}$) along the y-axis of antenna array **42** can be represented by the following equation:

$$S_{Y_N} = AF_{y1} = \sum_{n=1}^{N} I_{n1} e^{j(n-1)(kd_x \sin\theta\sin\Phi+\beta_y)}$$

where I_{n1} (n=1, . . . , N) is an excitation amplitude of an antenna of antenna array **42** at a point represented by $y=(n-1)d_y$; d_y is a distance between antennas of antenna array **42** in a y-direction (for simplicity, assume antennas of antenna array **42** are equispaced); β_y represents a progressive phase shift (a phase shift between adjacent antennas of antenna array **42** in the y-direction); and sin θ sin Φ is a directional cosine with respect to the y-axis. Then, the array factor for the entire antenna array **42** can be represented by the following equation:

$$AF = S_{X_M} S_{Y_N} =$$

$$AF_{y1} = \sum_{n=1}^{N} I_{n1} \left[\sum_{m=1}^{M} I_{m1} e^{j(m-1)(kd_x \sin\theta\cos\Phi+\beta_x)} \right] e^{j(n-1)(kd_y \sin\theta\sin\Phi+\beta_y)}$$

where a shape of the array factor for antenna array **42** can be controlled by the following parameters: extinction coefficients of each antenna element (for example, I_{n1}, I_{m1}), distance between antennas (for example, d_x and d_y), and progressive phase shift between antennas (for example, β_x and β_y).

FIG. **4**A, FIG. **4**B, FIG. **4**C, and FIG. **4**D illustrate array factors that can be achieved by varying antenna array parameters (such as number of antennas and/or progressive phase shifts), and thereby achieve different radiation patterns for beamformed signal **38**, according to various aspects of the present disclosure. Each array factor is plotted as a two-dimensional representation as a function of angle θ and a constant angle Φ (such as 45 degrees). A two-by-two antenna array with a 0 degree progressive phase shift can be represented by array factor A (FIG. **4**A), a 225 degree progressive phase shift can be represented by array factor B (FIG. **4**B), and a 135 degree phase shift can be represented by array factor C (FIG. **4**C). In various embodiments, adjusting the phase shift of the two-by-two antenna can change a shape of the array factor to concentrate radiated energy at different locations, for example, different locations within and/or around wireless network system **12**. A four-by-four antenna array with a 0 degree progressive phase shift can be represented by array factor D (FIG. **4**D). In various embodiments, a shape of array factor D (arising from the four-by-four antenna array) can concentrate radiated energy at larger distances than a shape of array factor A (arising from the two-by-two antenna array). FIGS. **4**A-**4**D have been simplified for the sake of clarity to better understand the inventive concepts of the present disclosure.

Returning to FIGS. **2**A-**2**C, REDDA module **40** further includes a beamformer mechanism **52** for producing beamformed signal **38**, which can include controller **50**, an RF transceiver **54** (in various embodiments, an agile wideband RF transceiver), a power splitter **56**, and a phase shifter and a power amplifier associated with each antenna E**1**, E**2**, E**3**, and E**4** (phase shifters **58** and power amplifiers **60**). Controller **50** communicates with RF transceiver **54**, power splitter **56**, phase shifters **58**, and power amplifiers **60** to achieve various radiation patterns for beamformed signal **38**. For example, controller **50** can provide a signal to RF transceiver **54**, which processes the signal to provide an RF input signal to power splitter **56**, which can split (or divide) the RF input signal into various RF signal components (here, four RF signal components). In various embodiments, a processing stage associated with each antenna E**1**, E**2**, E**3**, and E**4** of antenna array **42** receives an RF signal component from power splitter **56**. In the depicted embodiment, each phase shifter **58** receives a corresponding RF signal component from power splitter **56** (indicated by solid arrows) and a corresponding phase shift component from controller **50** (indicated by dashed arrows) (for example, a programmed, specific phase shift for each antenna of antenna array **42**). Each phase shifter **58** can introduce its corresponding phase shift component into its corresponding RF signal component to produce phase-shifted transmit signal components, which are provided to power amplifiers **60**. Each antenna E**1**, E**2**, E**3**, and/or E**4** can transmit (radiate) respective RF signals **44**(**1**), **44**(**2**), **44**(**3**), and **44**(**4**) responsive to its corresponding amplified, phase-shifted transmit signal component, which combine to produce beamformed signal **38**.

Controller **50** can adjust extinction coefficients and progressive phase shifts associated with antenna array **42**, such that RF signals **44** associated with antennas E**1**, E**2**, E**3**, and E**4** combine to optimize beamformed signal **38**. In various embodiments, controller **50** adjusts various array parameters to achieve one of thirty-two beam options (Beam Option **1**, Beam Option **2**, . . . Beam Option **32**). By adjusting various antenna parameters (such as the extinction coefficients and the progressive phase shifts), REDDA system **36** can selectively charge and/or power on/off sensor nodes **20**. For example, where a sensor node **20** has a battery (for example, where sensor node **20** includes an active or semi-passive RFID tag), REDDA system **36** can provide beamformed signal **38** with a radiation pattern that selectively charges the battery, in some embodiments, to lengthen a lifetime of the

battery. The radiation pattern can be adjusted to maximize wireless charging of the battery and optimize a rate of transfer of RF energy to the sensor node **20**. In another example, where a sensor node **20** is battery free (for example, where sensor node **20** includes a passive RFID tag), REDDA system **36** can provide beamformed signal **38** with a radiation pattern that selectively turns on/off the sensor node **20**. In some embodiments, the radiation pattern can be adjusted to turn some sensor nodes **20** on while turning other sensor nodes **20** off. The radiation pattern can further be adjusted to maximize wireless power transmission to the sensor nodes **20** to optimize charging and/or powering on time for sensor nodes **20**.

In various embodiments, adjusting various antenna parameters to provide beamformed signal **38** with various radiation patterns provides a programmable quality of service (QoS) metric for wireless power transmission. For example, controller **50** can adjust extinction coefficients and progressive phase shifts associated with antenna array **42** to produce radiation patterns for beamformed signal **38** having different QoS. QoS can refer to a defined level of performance in wireless network system **12** and/or communication system **10**. Different radiation patterns of beamformed signal **38** can achieve different QoS, depending on communication requirements of communication system **10**, wireless network system **12**, sensor nodes **20**, gateway node **22**, REDDA system **36**, and/or REDDA module **40**. In various embodiments, sensor nodes **20** located in one portion of wireless sensor network **12** may need to receive RF energy with a different QoS than sensor nodes **20** located in another part of wireless sensor network **12**. In various embodiments, wireless sensor network **12** can be configured for machine health monitoring. In such configurations, a machine may send an alert to gateway node **22** that indicates a problem associated with the machine (for example, the machine may need more power and/or increase data transmission frequency). Gateway node **22** can produce a radiation pattern that elevates (increases) QoS of the beamformed signal **38** received by the machine, such that the machine receives more power and/or gateway node **22** scans the machine more frequently to increase data transmission frequency. Such QoS can remain elevated until resolving the problem associated with the machine. In various embodiments, the machine can communicated with gateway node **22** over an IoT port, such as that described below, where the machine can report the problem to the gateway node **22**, and notify gateway node **22** when the problem has been resolved.

In various embodiments, REDDA module **40** can maximize wireless power transmission based on changes in network environment of wireless network system **20**, such as changes in location of sensor nodes **20**, gateway node **20**, and/or things within and/or around wireless network system **12**. For example, REDDA system **36** can evaluate its surrounding network environment to determine an appropriate radiation pattern for beamformed signal **38** that maximizes wireless power transmission, and thus maximizes wireless charging of sensor nodes **20**. Different environment parameters can be evaluated based on information collected from sensor nodes **20**, network elements within and/or around wireless network system **12**, and/or network elements over network **32**. In various embodiments, REDDA module **40** can use a programmable beamformer sector profile table to maximize wireless power transmission (for example, maximize RF energy transfer efficiency) to sensor nodes **20**. For example, REDDA module **40** can include a memory **62** that stores a beamformer sector profile table **64** that defines various beam profiles for beamformed signal **38**, where each beam profile maximizes wireless power transmission for a given environment associated with sensor nodes **20**. In various embodiments, each beam profile defines a radiation pattern for beamformed signal **38**, along with array parameters that can be implemented to achieve the defined radiation pattern. Each beam profile can further define various network and/or system characteristics that benefit from the beam profiles, such as number/location of sensor nodes **20**, type of sensor nodes **20**, number/location of other objects or things situated near sensor nodes **20**, characteristics of wireless network system **12**, characteristics of communication system **10**, characteristics of sensor nodes **20** and/or gateway node **22**, and/or other environmental characteristics that may affect transmission of beamformed signal **38** to the sensor nodes **20**. Controller **50** can select a beam profile from the beamformer sector profile table **64** to maximize wireless power transmission within a given area of wireless network system **12** and/or within a coverage area of gateway node **22**. It is noted that beamformer sector profile table **64** can be stored in any form, not necessarily tabular form.

FIG. **5** is a schematic diagram of an exemplary gateway node **22** that uses a programmable beamformer sector profile table to maximize wireless power transmission in different areas according to various aspects of the present disclosure. In FIG. **5**, gateway node **22** has a coverage area A, where gateway node **22** aggregates data from and wirelessly transmits power to sensor nodes **20** within coverage area A. In various embodiments, coverage area A is divided into sectors **72**, such as a sector **72**A, a sector **72**B, a sector **72**C, and a sector **72**D. Sectors **72** can have various dimensions and/or configurations depending on design considerations for wireless network system **12**, sensor nodes **20**, and/or gateway node **22**. For each sector **72**, gateway node **22** (for example, REDDA system **36**) can define a beam profile, and thus a given radiation pattern, for beamformed signal **38** based on various characteristics of the sector, such as number/location of sensor nodes **20**, type of sensor nodes **20**, reflection characteristics of surrounding environment of sensor nodes **20** and/or gateway node **22**, and/or other characteristics associated with each sector **72**, such as objects or things that may interfere with sensor nodes **20** receiving beamformed signal **38**. The defined beam profiles can be stored in beamformer sector profile table **74**. For example, in FIG. **5**, beamformed signal **38** has a different beam profile (radiation pattern) in sector **72**A, sector **72**B, sector **72**C, and sector **72**D, such that beamformed signal **38** maximizes wireless transmission (such as RF energy transfer efficiency) to sensor nodes **20** in sector **72**A, sector **72**B, sector **72**C, and sector **72**D. In various embodiments, where a sector has too much reflection, a radiation pattern of beamformed signal **38** can be adjusted to boost wireless energy transfer within the sector. FIG. **5** has been simplified for the sake of clarity to better understand the inventive concepts of the present disclosure. Additional features can be added, and some of the features described can be replaced or eliminated in other embodiments.

Turning again to FIGS. **2**A-**2**C, as noted above, gateway node **22** can communicate the collected data to network elements of wireless network system **12** or to network elements over network **32**. In FIG. **2**A, REDDA module **40** can also include an interface **80** that connects REDDA module **40** to network elements within wireless network system **12**, such as a network element **82**, or to network elements over network **32**, such as network element **84**. In some embodiments, network element **82** can be connected to network **32**. Interface **80** can include an Ethernet interface **86** and/or a universal serial bus (USB) interface **86** for

connecting to other networks, network elements, and/or applications. In various embodiments, interface **80** is an IoT interface that connects REDDA module **40** to an IoT system through a wired and/or wireless connection. For example, REDDA module **40** can be connected to the Internet. In various embodiments, network element **82** and/or network element **84** can be implemented as a host computer system that processes information collected from sensor nodes **20** via REDDA module **20**. In various embodiments, gateway node **22** can directly communicate with the Internet and/or Internet connected entities and/or with other networks and/or network connected entities (such as a robot network, as described further below) via the IoT interface. In various embodiments, the IoT interface facilitates building a mesh network out of more than one REDDA system **36**, where the REDDA systems **36** can communicate with one another and data mine over wireless network system **12**. In some embodiments, REDDA system **36** can data mine over wireless network system **12** via the IoT interface to better define an appropriate radiation pattern for beamformed signal **38**. In some situations, REDDA module **40** sets the radiation pattern of the beamformed signal **38** based on information gleaned from the IoT system. REDDA system **36** can thus set a radiation pattern for beamformed signal **38** and/or QoS for beamformed signal **38** based on data mining results from wireless network system **12** and/or based on IoT requests.

In various embodiments, wireless network system **12** can represent a global positioning system (GPS) denied network environment. REDDA module **40** can be configured to have location awareness in the GPS defined environment, such that controller **50** can have location awareness for determining radiation patterns for beamformed signal **38** that maximize wireless power transmission, and then use location awareness to update beamformer sector profile table **64**. REDDA module **40** can thus use location awareness to maximize wireless power transmission in various sectors of wireless network system **12** and/or sectors of coverage area of gateway node **22**. FIG. **6** is a schematic diagram of an exemplary communication system **10** that provides location awareness to REDDA module **40** according to various aspects of the present disclosure. In FIG. **6**, sensor nodes **20** include robots **26**, where each robot **26** has an associated inertial measurement unit (IMU) **90**. IMUs **90** can generally include embedded instrumentation, such as gyroscopes, 3D accelerometers, 3D gyroscopes, velocity meters, and/or or other inertial sensors, for determining positional data, such as altitude, location, motion, and/or other positional parameter, which can be used to determine a current position of its associated sensor node **20**. In various embodiments, each sensor (for example, sensor **28**) of sensor nodes **20** can include an IMU **90** for providing positional data associated with the sensor. In various embodiments, IMUs **90** communicate positional data to REDDA system **36** via data signals **30**. Alternatively, in various embodiments, IMUs **90** communicate positional data to network element **82** and/or network element **84**, where REDDA system **36** receives the positional data information from network element **82** and/or network element **84**. Using the positional data associated with sensor nodes **20**, REDDA module **40** can update beamformer sector profile table **64** to ensure optimal wireless power transfer (optimal wireless charging) to sensor nodes **20** of wireless network system **12**. In various embodiments, based on positional data, REDDA module **40** can adjust a radiation pattern of beamformed signal **38** to maximize RF energy transfer to a given area, thus maximizing charging and/or powering on/off of sensor nodes **20** within the given area. In various embodiments, robots **26** wirelessly communicate with one another in wireless network system **12** via communication signals **92**, for example, over a robot communications network. REDDA module **40** can adjust a radiation pattern of beamformed signal **38** by gleaning information from the robot communications network. In various embodiments, robots **26** communicate with one another to optimize positional data information, such that REDDA module **40** can glean information from the collective wisdom of robots **26** to determine beam profiles for beamformer sector profile table **64**. In various embodiments, gateway node **22** is configured to update beamformer sector profile table **64** based on collective wisdom between robots **26**. In an example, each robot **26** can include gateway node **22** and/or REDDA system **36**, where REDDA system **36** collects data from its associated robot **26** and wirelessly powers sensors **28** of its associated robot **26**. By reading sensors **28** (in some embodiments, RFID tags of its associated robot **26**), REDDA system **36** can enable its associated robot **26** to navigate within and/or around wireless network system **12**, particularly useful when wireless network system **12** is configured as a GPS denied environment. In some embodiments, REDDA system **36** can use collective wisdom of robots **26** to navigate within and/or around wireless network system **12**. In some embodiments, REDDA system **36** can use collective wisdom of robots **26** to optimize its associated beamformer sector profile table **64**. The present disclosure thus contemplates situations where gateway node **22** and/or REDDA system **36** are static or dynamic within and/or around wireless network system **12**. FIG. **6** has been simplified for the sake of clarity to better understand the inventive concepts of the present disclosure. Additional features can be added, and some of the features described can be replaced or eliminated in other embodiments.

FIG. **7**A is a simplified flowchart of an exemplary method **100** for wirelessly transmitting power that can be implemented by a gateway node to wirelessly charge sensor nodes, such as gateway node **22** to wirelessly charge sensor nodes **20**, according to various aspects of the present disclosure. At block **102**, a radiation pattern is determined for a beamformed signal based on an environment associated with sensor nodes. For example, gateway node **22** can evaluate an environment associated with sensor nodes **20** to determine a radiation patter form a beamformed signal transmitted to sensor nodes **20**. At block **104**, antenna parameters of an antenna array are adjusted, such that the antenna array wirelessly transmits power to the sensor nodes by producing a beamformed signal having the determined radiation pattern. For example, gateway node **22** adjusts antenna parameters (for example, using controller **50**) of antenna array **42** to achieve the determined radiation pattern for beamformed signal **38**. Gateway node **22** can optimize wireless power transmission to sensor nodes **20** by producing beamformed signal **38** having the determined radiation pattern. Additional steps can be provided before, during, and after method **100** and some of the steps described can be replaced or eliminated for other embodiments of method **100**.

FIG. **7**B is a simplified flowchart of another exemplary method **110** for wirelessly transmitting power that can be implemented by a gateway node to wirelessly charge sensor nodes, such as gateway node **22** to wirelessly charge sensor nodes **20**, according to various aspects of the present disclosure. At block **112**, sectors of a coverage area of a gateway node are defined. For example, gateway node **22** can define various sectors of coverage area A. At block **114**, for a sector, a beamformed signal is adjusted based on sector characteristics, such that the adjusted beamformed signal

maximizes wireless power transfer to sensor nodes within the sector. For example, gateway node **22** can evaluate an environment associated with the sector, including number and/or location of sensor nodes **20** within the sector, and then adjust beamformed signal **38** transmitted to the sector based on the environment. At block **116**, wireless power is transmitted to the sensor nodes within the sector using the adjusted beamformed signal. For example, gateway node **22** can adjust a radiation pattern of beamformed signal **38** delivered to the sector, where the adjusted radiation pattern maximizes wireless power transmission to sensor nodes **20** within the sector. Additional steps can be provided before, during, and after method **110** and some of the steps described can be replaced or eliminated for other embodiments of method **110**.

In various implementations, components of the FIGURES can be implemented on a board of an associated electronic device. The board can be a general circuit board that can hold various components of an internal electronic system of the electronic device and, further, provide connectors for other peripherals. The board can provide the electrical connections by which the other components of the system can communicate electrically. Any suitable processors (inclusive of digital signal processors, microprocessors, supporting chipsets, etc.), memory elements, etc. can be suitably coupled to the board based on particular configuration needs, processing demands, computer designs, other considerations, or a combination thereof. Other components, such as external storage, sensors, controllers for audio/video display, and peripheral devices may be attached to the board as plug-in cards, via cables, or integrated into the board itself. In various implementations, components of the FIGURES can be implemented as stand-alone modules (for example, a device with associated components and circuitry configured to perform a specific application or function) or implemented as plug-in modules into application specific hardware of electronic devices. Note that particular embodiments of the present disclosure may be readily included in a system-on-chip (SOC) package, either in part, or in whole. An SOC represents an integrated circuit that integrates components of a computer or other electronic system into a single chip. It may contain digital, analog, mixed-signal, and often radio frequency functions: all of which may be provided on a single chip substrate. Other embodiments may include a multi-chip-module (MCM), with a plurality of separate ICs located within a single electronic package and configured to interact closely with each other through the electronic package. In various other embodiments, the various functions described herein may be implemented in one or more semiconductor cores (such as silicon cores) in application specific integrated circuits (ASICs), field programmable gate arrays (FPGAs), other semiconductor chips, or combinations thereof.

The various functions outlined herein may be implemented by logic encoded in one or more non-transitory and/or tangible media (for example, embedded logic provided in an application specific integrated circuit (ASIC), as digital signal processor (DSP) instructions, software (potentially inclusive of object code and source code) to be executed by a processor, or other similar machine, etc.). In some of these instances, a memory element can store data used for the operations described herein. This includes the memory element being able to store logic (for example, software, code, processor instructions) that is executed by a processor to carry out the activities described herein. The processor can execute any type of instructions associated with the data to achieve the operations detailed herein. In various implementations, the processor can transform an element or an article (such as data) from one state or thing to another state or thing. In another example, the activities outlined herein may be implemented with fixed logic or programmable logic (such as software/computer instructions executed by the processor) and the elements identified herein can be some type of a programmable processor (such as a DSP), programmable digital logic (e.g., a FPGA, an erasable programmable read only memory (EPROM), an electrically erasable programmable ROM (EEPROM)), or an ASIC that includes digital logic, software, code, electronic instructions, or any suitable combination thereof.

Note that the activities discussed above with reference to the FIGURES are applicable to any integrated circuits that involve signal processing, particularly those that can execute specialized software programs or algorithms, some of which may be associated with processing digitized real-time data. Certain embodiments can relate to multi-DSP signal processing, floating point processing, signal/control processing, fixed-function processing, microcontroller applications, etc. In certain contexts, the features discussed herein can be applicable to medical systems, scientific instrumentation, wireless and wired communications, radar, industrial process control, audio and video equipment, current sensing, instrumentation (which can be highly precise), and other digital-processing-based systems. Moreover, certain embodiments discussed above can be provisioned in digital signal processing technologies for medical imaging, patient monitoring, medical instrumentation, and home healthcare. This could include pulmonary monitors, accelerometers, heart rate monitors, pacemakers, etc. Other applications can involve automotive technologies for safety systems (e.g., stability control systems, driver assistance systems, braking systems, infotainment and interior applications of any kind). Furthermore, powertrain systems (for example, in hybrid and electric vehicles) can use high-precision data conversion products in battery monitoring, control systems, reporting controls, maintenance activities, etc. In yet other example scenarios, the teachings of the present disclosure can be applicable in the industrial markets that include process control systems that help drive productivity, energy efficiency, and reliability. In consumer applications, the teachings of the signal processing circuits discussed above can be used for image processing, auto focus, and image stabilization (e.g., for digital still cameras, camcorders, etc.). Other consumer applications can include audio and video processors for home theater systems, DVD recorders, and high-definition televisions. Yet other consumer applications can involve advanced touch screen controllers (e.g., for any type of portable media device). Hence, such technologies could readily be a part of smartphones, tablets, security systems, PCs, gaming technologies, virtual reality, simulation training, etc.

The specifications, dimensions, and relationships outlined herein have only been offered for purposes of example and teaching only. Each of these may be varied considerably without departing from the spirit of the present disclosure, or the scope of the appended claims. The specifications apply only to non-limiting examples and, accordingly, they should be construed as such. In the foregoing description, example embodiments have been described with reference to particular processor and/or component arrangements. Various modifications and changes may be made to such embodiments without departing from the scope of the appended claims. The description and drawings are, accordingly, to be regarded in an illustrative rather than a restrictive sense.

Note that with the numerous examples provided herein, interaction may be described in terms of two, three, four, or more processing components. However, this has been done for purposes of clarity and example only. It should be appreciated that the system can be consolidated in any suitable manner. Along similar design alternatives, any of the illustrated components, modules, circuits, and elements of the FIGURES may be combined in various possible configurations, all of which are clearly within the broad scope of this Specification. In certain cases, it may be easier to describe one or more of the functionalities of a given set of flows by only referencing a limited number of processing components. It should be appreciated that the processing components of the FIGURES and its teachings are readily scalable and can accommodate a large number of components, as well as more complicated/sophisticated arrangements and configurations. Accordingly, the examples provided should not limit the scope or inhibit the broad teachings of the processing system and/or components as potentially applied to a myriad of other architectures.

Further, note that references to various features (e.g., elements, structures, modules, components, steps, operations, characteristics, etc.) included in "one embodiment", "example embodiment", "an embodiment", "another embodiment", "some embodiments", "various embodiments", "other embodiments", "alternative embodiment", and the like are intended to mean that any such features are included in one or more embodiments of the present disclosure, but may or may not necessarily be combined in the same embodiments. It is further noted that "coupled to" and "coupled with" are used interchangeably herein, and that references to a feature "coupled to" or "coupled with" another feature include any communicative coupling means, electrical coupling means, mechanical coupling means, other coupling means, or a combination thereof that facilitates the feature functionalities and operations, such as the security check mechanisms, described herein.

Numerous other changes, substitutions, variations, alterations, and modifications may be ascertained to one skilled in the art and it is intended that the present disclosure encompass all such changes, substitutions, variations, alterations, and modifications as falling within the scope of the appended claims. In order to assist the United States Patent and Trademark Office (USPTO) and, additionally, any readers of any patent issued on this application in interpreting the claims appended hereto, Applicant wishes to note that the Applicant: (a) does not intend any of the appended claims to invoke paragraph six (6) of 35 U.S.C. section 112 as it exists on the date of the filing hereof unless the words "means for" or "steps for" are specifically used in the particular claims; and (b) does not intend, by any statement in the specification, to limit this disclosure in any way that is not otherwise reflected in the appended claims.

OTHER NOTES, EXAMPLES, AND IMPLEMENTATIONS

In various implementations, a system is provided. The system can include means for wirelessly transmitting power to sensor nodes using a beamformed RF signal. The system can further include means for aggregating data from the sensor nodes. The 'means for' in these instances can include (but is not limited to) using any suitable component discussed herein, along with any suitable software, circuitry, hub, computer code, logic, algorithms, hardware, controller, interface, link, bus, communication pathway, etc. In various implementations, the system includes memory that includes instructions that when executed cause the system to perform any of the activities discussed herein.

What is claimed is:

1. A method for wirelessly charging a network of sensors and updating the position of same using a beamformed signal, the method comprising:

scanning for new sensors in a low-power mode;

storing a location of the new sensors in memory;

scanning for moved sensors in the low-power mode;

updating the location of the moved sensors in memory;

aggregating data from the network of sensors;

beamforming a wireless signal using an antenna array; and,

transmitting power to one or more sensors in the sensor network in a high-power mode using a beamformed radio frequency signal.

2. The method of claim **1** wherein the low-power mode uses a beamformed signal.

3. The method of claim **2** further comprising interrogating one or more sensors in the sensor network.

4. The method of claim **3** further comprising sending data from one or more sensors in the sensor network.

5. The method of claim **4** further comprising receiving the data from one or more sensors in the sensor network which is to be aggregated.

6. The method of claim **1**, wherein scanning uses beamforming in a reciprocity configuration.

7. The method of claim **1** further comprising charging a capacitor in the one or more sensors in the sensor network.

8. The method of claim **7** wherein the sensors in the sensor network are passive devices before charging.

9. A wireless charging platform for a wireless sensor network, the wireless charging platform comprising:

a radio frequency energy distributor and data aggregator system that includes an Internet of Things (IoT) interface connected to an IoT network and a transceiver, wherein the radio frequency energy distributor and data aggregator system is configured to:

scan for sensor nodes;

store a location of one or more sensor nodes in memory;

aggregate data wirelessly transmitted from sensor nodes; and,

wirelessly transmit power to the sensor nodes using a beamformed RF signal;

wherein, the wireless transmission capacitively charges the sensor nodes.

10. The wireless charging platform of claim **9**, wherein the radio frequency energy distributor and data aggregator system includes an electronically steered antenna array for transmitting the beamformed RF signal, wherein the radio frequency energy distributor and data aggregator system is configured to set a radiation pattern for the beamformed RF signal that maximizes RF energy transfer to the sensor nodes based on an environment associated with the sensor nodes.

11. The wireless charging platform of claim **10**, wherein the radio frequency energy distributor and data aggregator system is configured to glean information about the surrounding environment from the IoT network.

12. The wireless charging platform of claim **9**, wherein the radio frequency energy distributor and data aggregator system includes an electronically steered antenna array for transmitting the beamformed RF signal, wherein the radio frequency energy distributor and data aggregator system is configured to set a radiation pattern for the beamformed RF signal that achieves a defined quality of service for RF energy transfer.

13. The wireless charging platform of claim 12, wherein each antenna of the antenna array has an associated extinction coefficient and an associated progressive phase shift, the radio frequency energy distributor and data aggregator system configured to set the associated extinction coefficients and progressive phase shifts to achieve the defined qualify of service.

14. The wireless charging platform of claim 9, the radio frequency energy distributor and data aggregator system is further configured to selectively power on/off at least one sensor node having no battery by setting a radiation pattern of the beamformed RF signal.

15. The wireless charging platform of claim 9, the radio frequency energy distributor and data aggregator system is further configured to selectively charge a capacitor of at least one sensor node by setting a radiation pattern of the beamformed RF signal.

16. The wireless charging platform of claim 9, wherein the radio frequency energy distributor and data aggregator system is configured to aggregate data from the sensor node and wirelessly transmit power to the sensor node on different radio bands.

17. The wireless charging platform of claim 16, wherein the radio frequency energy distributor and data aggregator system includes a wideband aggregator receiver, the radio frequency energy distributor and data aggregator system configured to aggregate data from a sensor narrowband radio using the wideband aggregator receiver in a manner that avoids data collision and minimizes data retransmission.

18. The wireless charging platform of claim 10, wherein the radio frequency energy distributor and data aggregator system includes at least one radio frequency energy distributor and data aggregator module that can be configured to provide various antenna array configurations.

19. The wireless charging platform of claim 18, wherein each radio frequency energy distributor and data aggregator module includes at least one communication port for connecting to another radio frequency energy distributor and data aggregator module, wherein connected radio frequency energy distributor and data aggregator modules form the electronically steered antenna array.

20. The wireless charging platform of claim 9, wherein the sensor nodes are passive.

21. The wireless charging platform of claim 20, wherein the sensor nodes are powered by capacitors.

22. The wireless charging platform of claim 21, wherein the sensor nodes are not powered by batteries.

23. A radio frequency energy distributor and data aggregator for wirelessly charging a network of sensors, the apparatus comprising:

an Internet of Things (IoT) interface connected to an IoT network configured to wirelessly communicate with the network of sensors;

memory;

an antenna array;

a controller configured to:

scan for sensor nodes;

store a location of one or more sensor nodes in memory;

aggregate data wirelessly transmitted from sensor nodes; and,

wirelessly transmit power to the sensor nodes using a beamformed RF signal;

and,

wherein, the wireless power transmission uses a far-field, radio frequency signal.

24. A radio frequency energy distributor and data aggregator of claim 23, wherein the aggregated data is stored in the memory.

25. A radio frequency energy distributor and data aggregator of claim 23, wherein, the far-field, radio frequency signal is configured to be a non-inductive electromagnetic signal.

26. A radio frequency energy distributor and data aggregator of claim 25, wherein the far-field, radio frequency signal is not configured to be near-field inductive.

27. A radio frequency energy distributor and data aggregator of claim 23, wherein a sensor node from the network of sensor nodes is in a quiescent state upon receipt of the wireless power transmission.

28. A radio frequency energy distributor and data aggregator of claim 23, wherein sensor data from the network of sensors is identified by radio frequency identification (RFID).

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